

**WHITE, BIAXIALLY ORIENTED, FLAME-RETARDANT AND UV-RESISTANT
POLYESTER FILM WITH CYCLOOLEFIN COPOLYMER, ITS USE AND PROCESS
FOR ITS PRODUCTION**

Ursula MURSCHALL

Herbert PEIFFER

Hans MAHL

Gottfried HILKERT

Attorney-Docket-No. 00-057 MFE

09781539-024304
FOOTED: 8251826

The present invention relates to a white, biaxially oriented, flame-retardant, UV-resistant polyester film comprising at least one layer which comprises a polyester and a cycloolefin copolymer (COC). The invention further relates to the use of the polyester film, and to a process for its production.

5

Background of the Invention

White, biaxially oriented polyester films are known from the prior art. These known prior art films are either easy to produce, have good optical properties or have acceptable processing performance.

DE-A 2 353 347 describes a process for producing milky polyester film having one or more layers, which comprises preparing a mixture from particles of a linear polyester with from 3 to 27% by weight of a homopolymer or copolymer of ethylene or propylene, extruding the mixture as a film, quenching the film and biaxially orienting the film via orientation in directions running perpendicular to one another, and heat-setting the film. A disadvantage of this process is that regrind which arises during production of the film (essentially a mixture of polyester and ethylene or propylene copolymer) cannot be reused without yellowing the film. However, this makes the process uneconomic, but the film produced with regrind would not gain acceptance in the market. In addition, the roughness of the film is much too high, and this gives the film a very matt appearance (very low gloss), undesirable for many applications.

EP-A 0 300 060 describes a single-layer polyester film which comprises, besides polyethylene terephthalate, from 3 to 40% by weight of a crystalline propylene polymer and from 0.001 to 3% by weight of a surface-active substance. The effect of the surface-active substance is to increase the number of vacuoles in the film and at the same time to reduce their size to the desired extent. This gives the film greater opacity and lower density. A residual disadvantage of the film is that regrind which arises during production of the film (essentially a mixture of polyester and propylene homopolymer) cannot be reused without yellowing the film. However, this makes the film uneconomic, but the film produced with regrind would not gain acceptance in the

market. In addition, the roughness of the film is much too high, giving it a very matt appearance (very low gloss), undesirable for many applications.

5 EP-A 0 360 201 describes a polyester film having at least two layers and comprising a base layer with fine vacuoles, with a density of from 0.4 to 1.3 kg/dm³, and having at least one outer layer whose density is above 1.3 kg/dm³. The vacuoles are achieved by adding from 4 to 30% by weight of a crystalline propylene polymer, followed by biaxial stretching of the film. The additional outer layer improves the ease of production of the film (no streaking on the film surface), and the surface tension is increased and the roughness of the laminated surface can be reduced. A residual disadvantage is that regrind arising during production of the film (essentially a mixture of polyester and propylene homopolymer) cannot be reused without yellowing the film. However, this makes the process uneconomic, but the film produced with regrind would not gain acceptance in the market. In addition, the roughnesses of the films listed in the examples are still too high, giving the films a matt appearance (low gloss), undesirable for many applications.

10 EP-A 0 795 399 describes a polyester film having at least two layers and comprising a base layer with fine vacuoles, the density of which is from 0.4 to 1.3 kg/dm³, and having at least one outer layer, the density of which is greater than 1.3 kg/dm³. The vacuoles are achieved by adding from 5 to 45% by weight of a thermoplastic polymer to the polyester in the base, followed by biaxial stretching of the film. The thermoplastic polymers used are, inter alia, polypropylene, polyethylene, polymethylpentene, polystyrene or polycarbonate, and the preferred thermoplastic polymer is polypropylene. As a result of adding the outer layer, ease of production of the film is improved (no streaking on the film surface), the surface tension is increased and the roughness of the laminated surface can be matched to prevailing requirements. Further modification of the film in the base layer and/or in the outer layers, using white pigments (generally TiO₂) and/or using optical brighteners permits the properties of the film to be matched to the prevailing requirements of the application. A residual disadvantage is that regrind which arises during production of the film (essentially a mixture of

polyester and the added polymer) cannot be reused without undefined and highly undesirable changes in the color of the film. This makes the process uneconomic, but the film produced with regrind would not gain acceptance in the market. In addition, the films listed in the examples continue to have excessive roughness values, giving them a matt appearance (low gloss), undesirable for many applications.

DE-A 195 40 277 describes a polyester film having one or more layers and comprising a base layer with fine vacuoles, with a density of from 0.6 to 1.3 kg/dm³, and having planar birefringence of from -0.02 to 0.04. The vacuoles are achieved by adding from 3 to 40% by weight of a thermoplastic resin to the polyester in the base, followed by biaxial stretching of the film. The thermoplastic resins used are, inter alia, polypropylene, polyethylene, polymethylpentene, cyclic olefin polymers, polyacrylic resins, polystyrene or polycarbonate, preferred polymers being polypropylene and polystyrene. By maintaining the stated limits for the birefringence of the film, the film claimed has in particular superior tear strength and superior isotropy properties. However, a residual disadvantage is that regrind arising during production of the film cannot be reused without undefined discoloration of the film arising, and this in turn is highly undesirable. This makes the process uneconomic, but the film produced with regrind would not gain acceptance in the market. In addition, the roughnesses of the films listed in the examples are still too high, giving them a matt appearance (low gloss), undesirable for many applications.

DE-A 23 46 787 describes a flame-retardant polymer. Besides the polymer itself, its use for producing films and fibers is also described. However, the following shortcomings were apparent during production of films with this phospholane-modified polymer claimed in the DE-A:

- The polymer is very sensitive to hydrolysis and has to be very thoroughly predried.
- On drying with dryers of the prior art, the polymer coagulates, making it extremely difficult, or even impossible, to produce a film.

- The films produced, under conditions which are extreme and not cost-effective, embrittle when exposed to heat, i.e. their mechanical properties deteriorate sharply due to the rapid onset of embrittlement, making the film industrially unusable. This embrittlement arises after as little as 48 hours of exposure to heat.

The object of the present invention was to provide a white, biaxially oriented polyester film which has high gloss and improved ease of production, i.e. low production costs, and which moreover has high UV resistance combined with good heat resistance and flame retardancy. In particular, it should be possible for cut material (regrind) directly associated with the film production process to be reused in the production process at a concentration of from 10 to 70% by weight, based on the total weight of the film, without any resultant adverse effect on the physical or optical properties of the film produced with regrind. In particular, addition of regrind should not cause any significant yellowing of the film.

High UV resistance means that the film is damaged only slightly or not at all by sunlight or other UV radiation, and therefore that the films are suitable for outdoor applications and/or critical indoor applications. In particular, during outdoor use over a period of some years, the films should not yellow, embrittle or show surface-cracking, nor exhibit any impairment of mechanical properties. High UV resistance therefore means that the film absorbs UV light and does not begin to transmit light until the visible region has been reached.

High flame retardancy means that in what is known as a fire protection test the white film meets the requirements of DIN 4102, Part 2 and in particular the requirements of DIN 4102, Part 1 and can be classified in building materials class B2, in particular B1, for low-flammability materials.

The film should moreover pass the UL 94 test known as the "Vertical burning test for flammability of plastic materials", therefore qualifying for classification 94 VTM-0. This

means that the film ceases to burn within 10 seconds after removal of the bunsen burner, that no further smoldering is observed after 30 seconds, and that no flaming drops are observed over the entire period.

5 Cost-effective production includes the capability of the polymers or polymer components needed for producing the flame-retardant film to be dried using industrial dryers of the prior art. It is important that the polymers do not cake and do not undergo thermal degradation. These industrial dryers of the prior art include vacuum dryers, fluidized-bed dryers, moving-bed dryers and fixed-bed dryers (power dryers). The
10 dryers mentioned operate at temperatures of from 100 to 170°C, at which flame-retardant polymers usually cake and have to be dug out, making film production impossible.

In vacuum dryers, which have the gentlest drying action, the polymer passes through a range of temperature of from about 30 to 130°C at a pressure of 50 mbar. A process known as postdrying is then required, in a hopper at temperatures of from 100 to 130°C and with a residence time of from 3 to 6 hours. Even here, the known polymer cakes to
15 an extreme extent.

20 Good heat resistance means that the film and its mechanical properties do not deteriorate after 100 hours of annealing at 100°C in a circulating-air heating cabinet.

25 Detailed Description of the Invention

According to the invention, the object is achieved by means of a white, biaxially oriented, flame-retardant and UV-resistant polyester film with at least one base layer made from polyester, the characterizing features of which are that at least the base
30 layer also comprises, based on the weight of the base layer, from 2 to 60% by weight of a cycloolefin copolymer (COC), where the glass transition temperature of the

cycloolefin copolymer (COC) is within the range from 70 to 270°C, and that the film comprises at least one UV stabilizer as light stabilizer and a flame retardant, where at least the flame retardant, and preferably also the UV stabilizer, is fed directly as a masterbatch to the polyester during film production.

5

The white, biaxially oriented polyester film as defined in the present invention is a film of this type whose whiteness is above 70%, preferably above 75% and particularly preferably above 80%. In addition, the opacity of the film of the invention is above 55%, preferably above 60% and particularly preferably above 65%.

To achieve the desired whiteness of the film of the invention, the amount of COC in the base layer should be above 2% by weight, otherwise the whiteness is below 70%. On the other hand, if the amount of COC is above 60% by weight, the film is no longer cost-effective to produce, since the process of orienting the film becomes unreliable.

It is also necessary for the glass transition temperature of the COC used to be above 70°C. Otherwise, if the glass transition temperature of the COC used is below 70°C, the polymer mixture is difficult to process, since it becomes difficult to extrude. The desired whiteness is lost and use of regrind gives a film with a tendency toward increased yellowness. On the other hand, if the glass transition temperature of the COC selected is above 270°C the homogenization of the polymer mixture in the extruder will no longer be sufficient. This then gives a film with undesirably inhomogeneous properties.

In the preferred embodiment of the film of the invention, the glass transition temperature of the COCs used is within the range from 90 to 250°C, and in the particularly preferred embodiment it is within the range from 110 to 220°C.

Surprisingly, it has been found that a white, opaque, glossy film can be produced by adding a COC in the manner described above.

The whiteness and the opacity of the film can be adjusted with precision and adapted

to particular requirements by varying the amount and nature of the COC added. This means that the use of other commonly used whitening or opacifying additives can substantially be dispensed with. It was also highly surprising that the surface roughness of the film is substantially lower, and therefore the gloss of the film substantially higher, than for comparable films of the prior art. A quite sensational discovery was the additional effect that, despite the presence of UV stabilizer and flame retardant, regrind exhibits no tendency toward yellowing, as is observed when using polymeric additives, sensitive UV stabilizers and conventional flame retardants of the prior art.

None of the features described was foreseeable. This was particularly the case since COCs are evidently substantially incompatible with polyethylene terephthalate and are known to require stretching ratios and stretching temperatures similar to those for polyethylene terephthalate. Under these circumstances the skilled worker would not have expected that a white, opaque film with high gloss could be produced under these production conditions.

In the preferred and particularly preferred embodiments, the film of the invention has high/particularly high whiteness and high/particularly high opacity, while addition of regrind causes extremely little change in the color of the film.

The film of the invention comprises at least one UV stabilizer as light stabilizer, preferably fed by way of what is known as masterbatch technology, directly during film production, the amount of UV stabilizer being within the range from 0.01 to 5% by weight, based on the weight of the layer comprising the UV stabilizer.

Light, in particular the ultraviolet content of solar radiation, i.e. the wavelength region from 280 to 400 nm, causes degradation in thermoplastics, the results of which are not only a change in appearance due to color change or yellowing but also an extremely adverse effect on the mechanical and physical properties of the moldings or films made from the thermoplastics.

The suppression of this photooxidative degradation is of considerable industrial and economic importance, since without it many thermoplastics have drastically reduced scope of application.

- 5 The absorption of UV light by polyethylene terephthalates, for example, starts below 360 nm, increases markedly below 320 nm and is very pronounced below 300 nm. Maximum absorption occurs at between 280 and 300 nm.

10 In the presence of oxygen it is mainly chain cleavage which occurs, but without crosslinking. The predominant photooxidation products in quantity terms are carbon monoxide, carbon dioxide and carboxylic acids. Besides the direct photolysis of the ester groups, consideration has to be given to oxidation reactions which proceed via peroxide radicals, again to form carbon dioxide.

15 In the photooxidation of polyethylene terephthalates there can also be cleavage of hydrogen at the position α to the ester groups, giving hydroperoxides and decomposition products of these, and this may be accompanied by chain cleavage (H. Day, D.M. Wiles: J. Appl. Polym. Sci 16, 1972, p. 203).

- 20 UV stabilizers, i.e. light stabilizers which are UV absorbers, are chemical compounds which can intervene in the physical and chemical processes of light-induced degradation. Carbon black and other pigments can give some protection from light. However, these substances are unsuitable for pale-coloured films, since they cause discoloration or color change.

- 25 For the purposes of the invention, light stabilizers which are suitable UV stabilizers are those which absorb at least 70%, preferably 80%, particularly preferably 90%, of the UV light in the wavelength region from 180 to 380 nm, preferably from 280 to 350 nm. These are particularly suitable if they are thermally stable, i.e. do not decompose into
- 30 cleavage products, or cause evolution of gas, in the temperature range from 260 to 300°C. Examples of light stabilizers which are suitable UV stabilizers are 2-

hydroxybenzophenones, 2-hydroxybenzotriazoles, organonickel compounds, salicylic esters, cinnamic ester derivatives, resorcinol monobenzoates, oxanilides, hydroxybenzoic esters, sterically hindered amines and triazines, preferably the 2-hydroxybenzotriazoles and the triazines.

5

For the skilled worker it was highly surprising that the use of the combination according to the invention, made from COC and UV stabilizers with flame retardant, gave useful films with excellent properties. The person skilled in the art would probably have begun by attempting to achieve some degree of UV resistance by using an antioxidant, but would have immediately found that the film rapidly yellows on weathering.

With the background knowledge that UV stabilizers which absorb UV light and therefore have the potential for protection are known from the literature, the skilled worker would then probably have used commercially available UV stabilizers. He would then have found that

- the UV stabilizer has insufficient thermal stability and decomposes into cleavage products at temperatures of from 200 to 240°C, or causes evolution of gas, and
- he has to incorporate large amounts (from about 10 to 15% by weight) of UV stabilizer if the UV light is to be absorbed effectively, thus preventing damage to the film.

However, at these high concentrations he would have found that the film is yellow even immediately after production, with Yellowness Index differences (YID) around 25. He would also have found that mechanical properties are adversely affected. During orientation he would have encountered exceptional problems, such as:

- break-off due to lack of strength, i.e. modulus of elasticity;
- die deposits, causing variations in profile;
- roller deposits from the UV stabilizer, an effect causing impairment of optical properties (poor haze, adhesion problems, non-uniform surface);

- deposits in the stretching and setting frames, dropping onto the film.

It was therefore more than surprising that even low concentrations of the UV stabilizer of the invention achieve excellent UV protection. It was very surprising that, together
5 with this excellent UV protection,

- the Yellowness Index of the film is unchanged from that of an unstabilized film within the bounds of accuracy of measurement;
- there are no releases of gases, no die deposits and no frame condensation, and the film therefore has excellent optical properties and excellent profile and layflat;
- the UV-resistant film has excellent stretchability, and therefore can be produced in a reliable and stable manner on high-speed film lines at speeds of up to 420 m/min.

The film is therefore also cost-effective. It was also highly surprising that it is even possible to reuse regrind without any adverse effect on the Yellowness Index of the film.

If desired, the film of the invention may also comprise, based on the weight of the polyester, from 0 to 50 000 ppm, in particular from 20 to 30 000 ppm, particularly preferably from 50 to 25 000 ppm, of an optical brightener. The optical brightener is preferably fed to the polyester by way of what is known as masterbatch technology during film production.

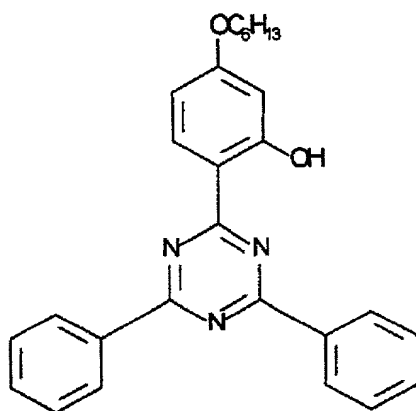
The optical brighteners which may, if desired, be added are capable of absorbing UV
25 radiation in the region from 360 to 380 nm and re-emitting this as longer-wavelength, visible blue-violet light.

Suitable optical brighteners are bisbenzoxazoles, phenylcoumarins and bisstearylbi-
phenyls, in particular phenylcoumarin, and particular preference is given to triazine phenylcoumarin, obtainable as ®Tinopal from Ciba-Geigy, Basle, Switzerland
30 and ®Hostalux KS (Clariant, Germany), and also ®Eastobrite OB-1 (Eastman).

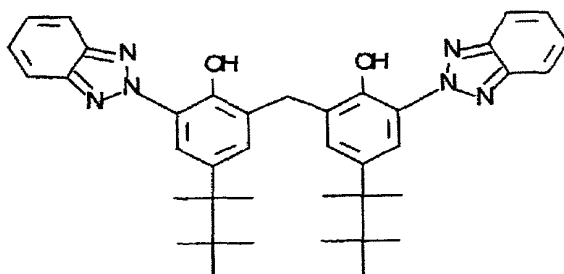
Besides the optical brightener, soluble blue dyes may also be added to the polyester if appropriate. Blue dyes which have proven suitable are cobalt blue, ultramarine blue and anthraquinone dyes, in particular Sudan Blue 2 (BASF, Ludwigshafen, Germany).

- 5 The amounts used of the blue dyes are from 0 to 10 000 ppm, in particular from 20 to 5000 ppm, particularly preferably from 50 to 1000 ppm, based on the weight of the polyester.

In one particularly preferred embodiment, the film of the invention comprises from 0.1 to 5.0% by weight of 2-(4,6-diphenyl-1,3,5-triazin-2-yl)-5-hexyloxyphenol of the formula:



or from 0.1 to 5.0% by weight of 2,2'-methylenebis(6-(2H-benzotriazol-2-yl)-4-(1,1,2,2-tetramethylpropyl)phenol) of the formula



In another embodiment it is also possible to use mixtures of these two UV stabilizers or mixtures of at least one of these two UV stabilizers with other UV stabilizers, the total concentration of light stabilizers preferably being from 0.1 to 5.0% by weight, preferably within the range from 0.5 to 3.0% by weight, based on the weight of the base layer.

The film of the invention comprises at least one flame retardant, which is fed by way of what is known as masterbatch technology directly during film production, the concentration of the flame retardant being within the range from 0.5 to 30.0% by weight, preferably from 1.0 to 20.0% by weight, based on the weight of the layer which comprises the flame retardant. During production of the masterbatch, the relationship between flame retardant and thermoplastic is generally within the range from 60% by weight:40% by weight to 10% by weight:90% by weight.

Typical flame retardants include bromine compounds, chloroparaffins and other chlorine compounds, antimony trioxide, and alumina trihydrates, the halogen compounds being disadvantageous since they produce halogen-containing byproducts. Other serious disadvantages are the low lightfastness of films in which these compounds are present, and the evolution of hydrogen halides in the event of a fire.

Examples of suitable flame retardants used according to the invention are organic phosphorus compounds, such as carboxyphosphinic acids, anhydrides thereof and dimethyl methylphosphonate. It is important for the invention that the organic phosphorus compound is soluble in the thermoplastic, since otherwise the optical

properties required are not complied with.

Since the flame retardants generally have some degree of susceptibility to hydrolysis, concomitant use of a hydrolysis stabilizer may be advisable.

5

The hydrolysis stabilizers used are generally amounts of from 0.01 to 1.0% by weight of phenolic stabilizers, of alkali metal/alkaline earth metal stearates and/or of alkali metal/alkaline earth metal carbonates. The amounts of phenolic stabilizers used are preferably from 0.05 to 0.6% by weight, in particular from 0.15 to 0.3% by weight, and their molar mass is preferably above 500 g/mol. Particularly advantageous compounds are pentaerythrityl tetrakis-3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate and 1,3,5-trimethyl-2,4,6-tris(3,5-di-tert-butyl-4-hydroxybenzyl)benzene.

10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100

It was more than surprising that by using masterbatch technology and a suitable predrying and/or precrystallization procedure and, if desired, using small amounts of a hydrolysis stabilizer, it is possible to produce a flame-retardant, thermoformable film with the required property profile cost-effectively and especially without any caking in the dryer, and that on exposure to high temperature the film does not embrittle, and does not break when folded.

20

It was very surprising that, together with this excellent result and with the flame retardancy required, and with the high UV resistance:

- the Yellowness Index of the film undergoes no adverse change when compared with that of an unstabilized film, within the bounds of accuracy of measurement;
- there are no releases of gases, no die deposits and no frame condensation, and the film therefore has excellent optical properties and excellent profile and layflat;
- the flame retardant, UV-resistant film has excellent stretchability, and therefore can be produced in a reliable and stable manner on high-speed film lines at speeds of 420 m/min.

25

30

The film is therefore also cost-effective.

5 The film of the invention has one or more layers. Single-layer embodiments have a structure like that of the COC-containing layer described below. Embodiments having more than one layer have at least two layers and always comprise the COC-containing layer and at least one other layer, where the COC-containing layer is the base layer but may also form the intermediate layer or the outer layer of the film having two or more layers. In one preferred embodiment, the COC-containing layer forms the base layer of the film with at least one outer layer and preferably outer layers on both sides, and an intermediate layer or intermediate layers may be present, if desired, on one or both sides. In another preferred embodiment, the COC-containing layer also forms an intermediate layer of the multilayer film. Other embodiments with COC-containing intermediate layers have a five-layer structure with COC-containing intermediate layers on both sides of the COC-containing base layer. In another embodiment, the COC-containing layer may form, as well as the base layer, an outer layer or outer layers on the base layer or intermediate layer, on one or both sides. For the purposes of the present invention, the base layer is that layer which makes up more than from 50 to 100%, preferably from 70 to 90%, of the total film thickness. The outer layer is always the layer which forms the outer layer of the film, and it is preferable for the invention if one or two outer layers have been arranged on the COC-containing base layer, and if both the UV stabilizer and the flame retardant are present in the outer layer(s).

25 Each embodiment of the invention is a non-transparent, white film. For the purposes of the present invention, non-transparent films are those films whose light transmittance to ASTM D1003-77 is below 95%, preferably below 75%.

30 The COC-containing layer (the base layer) of the film of the invention comprises a polyester, preferably a polyester homopolymer, a COC, the UV stabilizer, the flame retardant, and also, if desired, other additives, in each case in effective amounts. This layer generally comprises at least 20% by weight, preferably from 40 to 96% by weight,

in particular from 70 to 96% by weight, of polyester, based on the weight of the layer.

The base layer of the film comprises, as main constituent, a thermoplastic polyester. Polyesters suitable here are those made from ethylene glycol and terephthalic acid (= polyethylene terephthalate, PET), from ethylene glycol and naphthalene-2,6-dicarboxylic acid (= polyethylene 2,6-naphthalate, PEN), from 1,4-bishydroxymethylcyclohexane and terephthalic acid (= poly-1,4-cyclohexanedimethylene terephthalate, PCDT) or else from ethylene glycol, naphthalene-2,6-dicarboxylic acid and biphenyl-4,4'-dicarboxylic acid (= polyethylene 2,6-naphthalate bibenzoate, PENBB). Particular preference is given to polyesters which are composed of at least 90 mol%, preferably at least 95 mol%, of ethylene glycol units and terephthalic acid units or ethylene glycol units and naphthalene-2,6-dicarboxylic acid units. The remaining monomer units are derived from other aliphatic, cycloaliphatic or aromatic diols and, respectively, dicarboxylic acids, as may also be present in layer A (A = outer layer 1) or in layer C (C = outer layer 2) of a multilayered ABC (B = base layer) film.

Examples of other suitable aliphatic diols are diethylene glycol, triethylene glycol, aliphatic glycols of the formula $\text{HO}-(\text{CH}_2)_n\text{-OH}$, where n is an integer from 3 to 6 (in particular 1,3-propanediol, 1,4-butanediol, 1,5-pentanediol and 1,6-hexanediol) or branched aliphatic glycols having up to 6 carbon atoms. Among the cycloaliphatic diols, mention should be made of cyclohexanediols (in particular 1,4-cyclohexanediol). Other suitable aromatic diols are those, for example, of the formula $\text{HO-C}_6\text{H}_4\text{-X-C}_6\text{H}_4\text{-OH}$ where X is $-\text{CH}_2-$, $-\text{C}(\text{CH}_3)_2-$, $-\text{C}(\text{CF}_3)_2-$, $-\text{O}-$, $-\text{S}-$ or $-\text{SO}_2-$. Bisphenols of the formula $\text{HO-C}_6\text{H}_4\text{-C}_6\text{H}_4\text{-OH}$ are also highly suitable.

Other preferred aromatic dicarboxylic acids are benzenedicarboxylic acids, naphthalenedicarboxylic acids (such as naphthalene-1,4- or -1,6-dicarboxylic acid), biphenyl-x,x'-dicarboxylic acids (in particular biphenyl-4,4'-dicarboxylic acid), diphenylacetylene-x,x'-dicarboxylic acids (in particular diphenylacetylene-4,4'-dicarboxylic acid) and stilbene-x,x'-dicarboxylic acids. Among the cycloaliphatic

dicarboxylic acids mention should be made of cyclohexanedicarboxylic acids (in particular cyclohexane-1,4-dicarboxylic acid). Among the aliphatic dicarboxylic acids, the (C3-C19)-alkanedioic acids are particularly suitable, where the alkane moiety may be straight-chain or branched.

5

The polyesters may, for example, be prepared by the transesterification process. The starting materials here are dicarboxylic esters and diols, and these are reacted using the usual transesterification catalysts, such as salts of zinc, of calcium, of lithium, of magnesium or of manganese. The intermediates are then polycondensed in the presence of typical polycondensation catalysts, such as antimony trioxide or titanium salts. They may equally well be prepared by the direct esterification process in the presence of polycondensation catalysts, starting directly from the dicarboxylic acids and the diols.

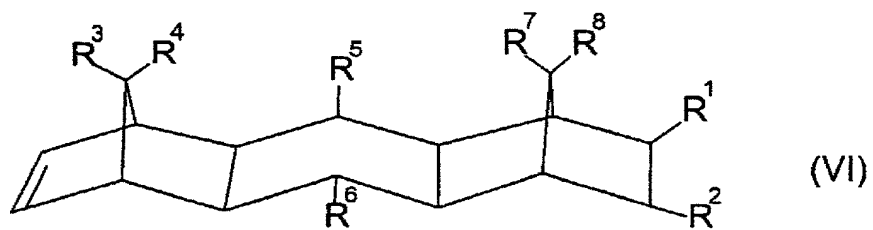
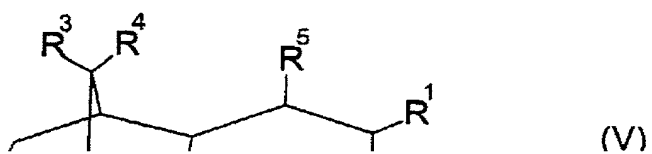
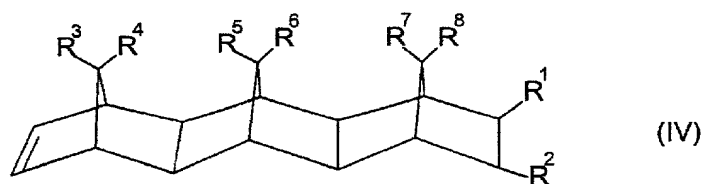
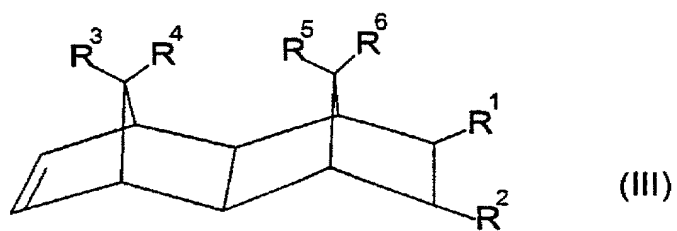
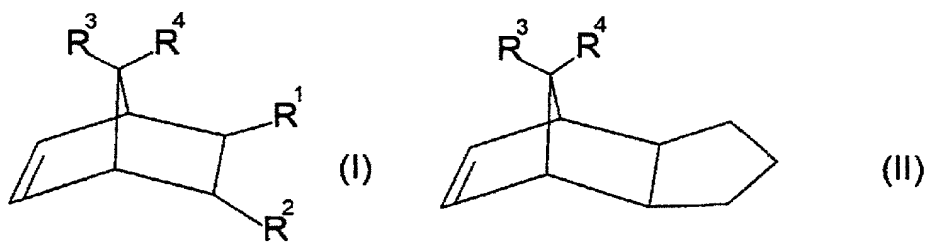
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100

20

According to the invention, the COC-containing layer (base layer) or, in the case of single-layer embodiments, the film, comprises an amount of not less than 2.0% by weight, preferably from 4 to 50% by weight and particularly preferably from 6 to 40% by weight, of a cycloolefin copolymer (COC), based on the weight of the base layer or, in the case of single-layer embodiments, based on the weight of the film. It is significant for the present invention that the COC is not compatible with the polyethylene terephthalate and does not form a homogeneous mixture with the same.

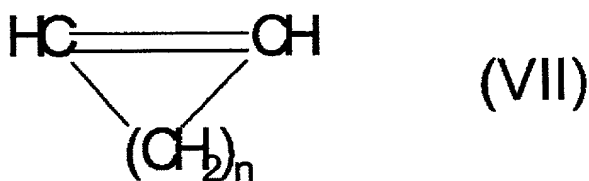
25

Cycloolefin polymers are homopolymers or copolymers which contain polymerized cycloolefin units and, if desired, acyclic olefins as comonomer. Cycloolefin polymers suitable for the present invention contain from 0.1 to 100% by weight, preferably from 10 to 99% by weight, particularly preferably from 50 to 95% by weight, of polymerized cycloolefin units, in each case based on the total weight of the cycloolefin polymer. Particular preference is given to polymers which have been built up using the monomers comprising the cyclic olefins of the formulae I, II, III, IV, V or VI:



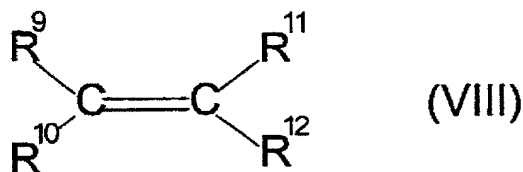
R1, R2, R3, R4, R5, R6, R7 and R8 in these formulae are identical or different and are a hydrogen atom or a C1-C30-hydrocarbon radical, or two or more of the radicals R1 to R8 have been bonded cyclically, and the same radicals in the different formulae may have the same or a different meaning. Examples of C1-C30-hydrocarbon radicals are linear or branched C1-C8-alkyl radicals, C6-C18-aryl radicals, C7-C20-alkylenearyl radicals and cyclic C3-C20-alkyl radicals and acyclic C2-C20-alkenyl radicals.

If desired, the COCs may contain from 0 to 45% by weight, based on the total weight of the cycloolefin polymer, of polymerized units of at least one monocyclic olefin of the formula VII:



n here is a number from 2 to 10.

If desired, the COCs may contain from 0 to 99% by weight, based on the total weight of the COC, of polymerized units of an acyclic olefin of the formula VIII:



R9, R10, R11 and R12 here are identical or different and are a hydrogen atom or a C1-C10-hydrocarbon radical, e.g. a C1-C8-alkyl radical or a C6-C14-aryl radical.

Other polymers suitable in principle are cycloolefin polymers which are obtained by ring-opening polymerization of at least one of the monomers of the formulae I to VI, followed by hydrogenation.

Cycloolefin homopolymers have a structure composed of one monomer of the formulae I to VI. These cycloolefin polymers are less suitable for the purposes of the present invention. Polymers suitable for the purposes of the present invention are cycloolefin copolymers (COC) which comprise at least one cycloolefin of the formulae I to VI and acyclic olefins of the formula VIII as comonomer. Acyclic olefins preferred here are those which have from 2 to 20 carbon atoms, in particular unbranched acyclic olefins having from 2 to 10 carbon atoms, for example ethylene, propylene and/or butylene. The proportion of polymerized units of acyclic olefins of the formula VIII is up to 99% by weight, preferably from 5 to 80% by weight, particularly preferably from 10 to 60% by weight, based on the total weight of the respective COC.

Among the COCs described above, those which are particularly preferred contain polymerized units of polycyclic olefins having a fundamental nor-bornene structure, particularly preferably norbornene or tetracyclododecene. Particular preference is also given to COCs which contain polymerized units of acyclic olefins, in particular ethylene. Particular preference is in turn given to norbornene-ethylene copolymers and tetracyclododecene-ethylene copolymers which in each case contain from 5 to 80% by weight, preferably from 10 to 60% by weight, of ethylene (based on the weight of the copolymer).

The cycloolefin polymers generically described above generally have glass transition temperatures T_g in the range from -20 to 400°C . However, COCs which can be used for the invention have a glass transition temperature T_g above 70°C , preferably above 90°C and in particular above 110°C . The viscosity number (decalin, 135°C , DIN 53 728) is advantageously from 0.1 to 200 ml/g, preferably from 50 to 150 ml/g.

The COCs are prepared by heterogeneous or homogeneous catalysis with organometallic compounds, as described in a wide variety of documents. Suitable catalyst systems based on mixed catalysts made from titanium compounds and, respectively, vanadium compounds in conjunction with aluminum organyl compounds

are described in DD 109 224, DD 237 070 and EP-A-0 156 464. EP-A-0 283 164, EP-A-0 407 870, EP-A-0 485 893 and EP-A-0 503 422 describe the preparation of COCs with catalysts based on soluble metallocene complexes. The preparation processes for COCs described in the abovementioned specifications are expressly incorporated herein by way of reference.

The COCs are incorporated into the film either in the form of pure granules or in the form of granulated concentrate (masterbatch), by premixing the polyester granules or polyester powder with the COC or, respectively, with the COC masterbatch, followed by feeding to an extruder. In the extruder, the mixing of the components continues and they are heated to the processing temperature. It is advantageous here for the novel process if the extrusion temperature is above the glass transition temperature T_g of the COC, generally above the glass transition temperature of the COC by at least 5 K, preferably by from 10 to 180 K, in particular by from 15 to 150 K.

For the intermediate layers and for the outer layers, it is possible in principle to use the polymers used for the base layer. Besides these, other materials may also be present in the outer layers, and the outer layers are then preferably composed of a mixture of polymers or of a copolymer or of a homopolymer which comprise ethylene 2,6-naphthalate units and ethylene terephthalate units. Up to 30 mol% of the polymers may be composed of other comonomers (e.g. ethylene isophthalate units).

The base layer and the other layers may additionally comprise conventional additives, such as stabilizers, antiblocking agents and other fillers. They are advantageously added to the polymer or, respectively, to the polymer mixture prior to melting. Examples of stabilizers used are phosphorus compounds, such as phosphoric acid or phosphoric esters.

Typical antiblocking agents (in this context also termed pigments) are inorganic and/or organic particles, such as calcium carbonate, amorphous silica, talc,

magnesium carbonate, barium carbonate, calcium sulfate, barium sulfate, lithium phosphate, calcium phosphate, magnesium phosphate, aluminum oxide, lithium fluoride, the calcium, barium, zinc or manganese salts of the dicarboxylic acids used, carbon black, titanium dioxide, kaolin or crosslinked polymer particles, e.g. polystyrene particles or acrylate particles.

The additives selected may also comprise mixtures of two or more different antiblocking agents or mixtures of antiblocking agents of the same composition but different particle sizes. The particles may be added to the polymers of the individual layers of the film in the respective advantageous amounts, e.g. as a glycolic dispersion during the polycondensation or via masterbatches during extrusion. Pigment concentrations which have proven particularly suitable are from 0 to 25% by weight (based on the weight of the respective layer). EP-A-0 602 964, for example, describes the antiblocking agents in detail.

To improve the whiteness of the film, the base layer or the other additional layers may comprise further pigmentation. It has proven particularly advantageous here for the additional materials added to be barium sulfate with a particle size of from 0.3 to 0.8 μm , preferably from 0.4 to 0.7 μm , or titanium dioxide with a particle size of from 0.05 to 0.3 μm . This gives the film a brilliant white appearance. The concentration of barium sulfate or titanium dioxide is within the range from 1 to 25% by weight, preferably from 1 to 20% by weight, and very preferably from 1 to 15% by weight.

The total thickness of the film may vary within wide limits and depends on the application envisaged. The preferred embodiments of the novel film have total thicknesses of from 4 to 400 μm , preferably from 8 to 300 μm , particularly preferably from 10 to 300 μm . The thickness of any intermediate layer(s) present is/are, in each case independently of one another, from 0.5 to 15 μm , preferably from 1 to 10 μm , in particular from 1 to 8 μm . All the values given are based on one intermediate layer. The thickness of the outer layer(s) is selected independently of the other

layers and is preferably within the range from 0.1 to 10 μm , in particular from 0.2 to 5 μm , preferably from 0.3 to 2 μm , and outer layers applied on both sides may be identical or different in terms of their thickness and composition. The thickness of the base layer is therefore given by the difference between the total thickness of the film and the thickness of the outer and intermediate layer(s) applied, and, similarly to the total thickness, may therefore vary within wide limits.

In one particular embodiment, the outer layers may also be composed of a polyethylene naphthalate homopolymer, or of an ethylene terephthalate-ethylene naphthalate copolymer, or of a compound.

In this embodiment, the standard viscosity of the thermoplastics of the outer layers is similar to that of the polyethylene terephthalate of the base layer.

In the embodiment having two or more layers, the UV stabilizer is preferably present in the outer layers. If required, the base layer may also have a UV stabilizer.

In the embodiments having two or more layers, the flame retardant is preferably present in the base layer. However, the outer layers may, if required, also have flame retardant.

In another embodiment, flame retardant and UV stabilizer may be present in the outer layers. If required, or if fire-protection requirements are stringent, the base layer may additionally comprise what is known as a base level of flame retardant.

Unlike in the single-layer embodiment, the amount of flame retardant and UV stabilizer here in percent by weight is based on the weight of the respective layer having the agents.

Very surprisingly, weathering tests to the ISO 4892 test specification using the Atlas Ci65 Weather-Ometer show that, to achieve improved UV resistance in a three-layer film, it is fully sufficient for the outer layers of from 0.5 to 2 μm thickness to have UV

stabilizers.

It is also surprising that fire tests to DIN 4102 Part 1 and Part 2, and also the UL 94 test, have shown that films of the invention comply with the requirements.

5

The flame-retardant, UV-resistant films having two or more layers and produced by known coextrusion technology are therefore of great interest in economic terms when compared with monofilms provided with full UV-resistance and flame retardancy, since markedly less additives are needed to achieve comparable flame retardancy and UV resistance.

10
15
20
25

Results from weathering tests reveal that the flame-retardant, white, UV-resistant films of the invention generally show no increase in yellowing, no embrittlement, no loss of surface gloss, no surface-cracking and no impairment of mechanical properties even after from 5 to 7 years (extrapolated from the individual weathering tests carried out) of outdoor use.

20

During production of the film it was found that the flame-retardant, UV-resistant film gives excellent longitudinal and transverse orientation without break-offs. In addition, no gas releases of any type attributable to the presence of UV stabilizer or flame retardant were found, and this is important for the invention, since most conventional UV stabilizers and flame retardants evolve very undesirable and unpleasant gases, attributable to the decomposition of these compounds under the conditions of processing, at extrusion temperatures above 260°C, and are therefore of no use.

25

Surprisingly, even films of the invention in the range of thickness from 5 to 300 µm comply with requirements for the construction materials class B1 to DIN 4102 Part 1 and with those for the UL 94 test.

30

During production of the white, flame-retardant, UV-resistant film it was also found that the flame retardant can be incorporated using masterbatch technology and

suitable predrying and/or precrystallization of the flame retardant masterbatch without the occurrence of caking in the dryer, and therefore the film can be produced cost-effectively.

5 It was more than surprising that incorporation is made even easier by small additions of a hydrolysis stabilizer within the flame retardant masterbatch. Throughputs, and therefore production rates, could readily be increased in this way. In one very specific embodiment, the film also comprises small amounts of a hydrolysis stabilizer in the layers having flame retardant.

10 Measurements showed that the film of the invention does not embrittle over long periods at high temperatures of 100°C, a fact which is more than surprising. This result is attributable to the synergistic action of suitable precrystallization, predrying, masterbatch technology and provision of UV stabilizer.

15 The film of the invention can moreover readily be recycled without pollution of the environment and without loss of mechanical properties, and examples of uses for which it is suitable are therefore short-lived promotional placards for constructing exhibition stands and other promotional requisites where fire protection is desirable.

20 The invention further provides a process for producing the polyester film of the invention by the extrusion or coextrusion process known per se.

25 According to the invention, the flame retardant, with or without the hydrolysis stabilizer, is fed by way of masterbatch technology. The flame retardant is fully dispersed in a carrier material. Carrier materials which may be used are the polyester itself, e.g. the polyethylene terephthalate, or else other polymers compatible with the polyester.

30 According to the invention, the UV stabilizer may be added at an early stage by the producer of the polyester, or may be fed into the extruder during film production.

It is particularly preferable for the UV stabilizer to be added by way of masterbatch technology. The UV stabilizer is fully dispersed in a solid carrier material. Carrier materials which may be used are certain resins, the polyester itself, e.g. the polyethylene terephthalate, or else other polymers compatible with the polyester.

5

It is important in masterbatch technology that the particle size and the bulk density of the masterbatch are similar to the particle size and the bulk density of the polyester, so that homogeneous distribution is achieved, giving uniform UV stabilization.

The polyester films may be produced by known processes from polyester with, if desired, other polymers, with the flame retardant, with or without the hydrolysis stabilizer, with the UV stabilizer and/or with other customary additives in customary amounts of from 1.0 to a maximum of 30% by weight, either in the form of a monofilm or else in the form of, if desired coextruded, films having two or more layers and with identically or differently constructed surfaces, where one surface may have been pigmented, for example, but no pigment is present at the other surface. Known processes may also have been used to provide one or both surfaces of the film with a conventional functional coating.

20

It is important for the invention that the masterbatch which comprises the flame retardant and, if used, the hydrolysis stabilizer, is precrystallized or predried. This predrying includes, for example, gradual heating of the masterbatch at reduced pressure (from 20 to 80 mbar, preferably from 30 to 60 mbar, in particular from 40 to 50 mbar) with agitation, and, if desired, post-drying at a constant, elevated temperature, again at reduced pressure. It is preferable for the masterbatch to be charged at room temperature from a metering vessel in the desired blend together with the polymer of the base and/or outer layers and, if desired, with other raw material components batchwise into a vacuum dryer in which the temperature profile moves from 10 to 160°C, preferably from 20 to 150°C, in particular from 30 to 130°C, during the course of the drying time or residence time. During the residence time of

25

30

about 6 hours, preferably 5 hours, in particular 4 hours, the raw material mixture is stirred at from 10 to 70 rpm, preferably from 15 to 65 rpm, in particular from 20 to 60 rpm. The resultant precrystallized or predried raw material mixture is post-dried in a downstream vessel, likewise evacuated, at temperatures of from 90 to 180°C, preferably from 100 to 170°C, in particular from 110 to 160°C, for from 2 to 8 hours, preferably from 3 to 7 hours, in particular from 4 to 6 hours.

For the coextrusion process, the procedure is that the melt(s) corresponding to the single-layer film or to the individual layers of the film is/are extruded/coextruded through a flat-film die, the resultant film is drawn off for solidification on one or more rolls, the film is then biaxially stretched (oriented), and the biaxially stretched film is then heat-set and, if desired, corona- or flame-treated on the surface layer intended for further treatment.

The biaxial orientation is generally carried out in succession. For this, it is preferable to orient first longitudinally (i.e. in MD, the machine direction) and then transversely (i.e. in TD, perpendicularly to the machine direction). This orientates the molecular chains. The longitudinal orientation preferably takes place with the aid of two rolls rotating at different rates corresponding to the desired stretching ratio. For the transverse stretching, an appropriate suitable tenter frame is generally used.

Simultaneous orientation of the film of the invention in the two directions (MD and TD) with the aid of a tenter frame suitable for this purpose has proven not to be appropriate, since this stretching method gives a film which has insufficient whiteness and insufficient opacity.

The temperature at which the orientation is carried out may be varied over a relatively wide range and depends on the properties desired in the film. In general, the longitudinal stretching is carried out at from 80 to 130°C and the transverse stretching at from 90 to 150°C. The longitudinal stretching ratio is generally within the range from 2.5:1 to 6:1, preferably from 3:1 to 5.5:1. The transverse stretching

ratio is generally within the range from 3.0:1 to 5.0:1, preferably from 3.5:1 to 4.5:1.

In the heat-setting which follows, the film is held at a temperature of from 150 to 250°C for from about 0.1 to 10 s. The film is then cooled and then wound up in the usual manner.

To establish other desired properties, the film may be chemically treated or else corona- or, respectively, flame-treated. The intensity of treatment is selected such that the surface tension of the film is generally above 45 mN/m.

To establish other properties, the film may also be coated. Typical coatings have adhesion-promoting, antistatic, slip-improving or release action. It is clear that these additional coatings may be applied to the film by in-line coating using aqueous dispersions, prior to the transverse stretching procedure.

The particular advantage of the novel film is its high whiteness and high opacity, together with UV resistance and flame retardancy. Surprisingly, the gloss of the film was also very high. The whiteness of the film is above 70%, preferably above 75% and particularly preferably above 80%. The opacity of the novel film is above 55%, preferably above 60% and particularly preferably above 65%. The gloss of the novel film is above 80, preferably above 90 and particularly preferably above 100.

Another particular advantage of the invention is that regrind material produced directly during the production process can be reused at a concentration of from 10 to 70% by weight, based on the total weight of the film, without any significant negative effect on the physical properties of the film. In particular, the regrinded material (composed essentially of polyester and COC) does not give undefined changes in the color of the film, as is the case in the films of the prior art.

A further advantage of the invention is that the production costs of the novel film are comparable with those of conventional opaque films of the prior art. The other

properties of the novel film relevant to its processing and use remain essentially unchanged or are even improved.

The film has excellent suitability for packing foods or other consumable items which are sensitive to light and/or to air. It is also highly suitable for use in the industrial sector, e.g. for producing hot-stamping foils or as a label film. Besides this, the film is, of course, particularly suitable for image-recording papers, printed sheets, magnetic recording cards, to name just a few possible applications.

The processing performance and winding performance of the film, in particular on high-speed machines (winders, metallizers, printing machines and laminating machines) is exceptionally good. A measure of processing performance is the coefficient of friction of the film, which is below 0.6. A decisive factor affecting winding performance, besides a good thickness profile, excellent layflat and a low coefficient of friction, is the roughness of the film. It has become apparent that the winding of the novel film is particularly good if the average roughness is within the range from 50 to 250 nm while the other properties are complied with. The roughness may be varied within the stated range by, inter alia, varying the COC concentration and the process parameters in the production process.

The most important film properties according to the invention are again summarized at a glance in the table below (Table 1), thus providing a particularly clear picture.

The following values were measured to characterize the polymers and the films:

SV (DCA), IV (DCA)

The standard viscosity SV (DCA) is measured in dichloroacetic acid by analogy with DIN 53726.

The intrinsic viscosity (IV) is calculated as follows from the standard viscosity (SV)

$$IV (DCA) = 6.67 \cdot 10^{-4} SV (DCA) + 0.118$$

Surface defects and uniformity of coloration

Surface defects and uniformity of coloration are determined visually.

Weathering (on both sides) and UV resistance

5 UV resistance is tested as follows to the ISO 4892 test specification:

Test equipment	: Atlas Ci65 Weather-Ometer
Test conditions	: ISO 4892, i.e. artificial weathering
Irradiation time	: 1000 hours (per side)
Irradiation	: 0.5 W/m ² , 340 nm
Temperature	: 63°C
Relative humidity	: 50%
Xenon lamp	: Internal and external filter made from borosilicate
Irradiation cycles	: 102 minutes of UV light, then 18 minutes of UV light with water spray on the specimens, then again 102 minutes of UV light, etc.

10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169

Yellowness Index

The Yellowness Index YID is the deviation from the colorless state in the "yellow" direction and is measured to DIN 6167.

5 Fire performance

Fire performance is determined to DIN 4102, Part 2, construction materials class B2, and to DIN 4102, Part 1, construction materials class B1, and also by the UL 94 test.

Coefficient of friction

Coefficient of friction is determined to DIN 53 375. The coefficient of sliding friction was determined 14 days after production.

Surface tension

Surface tension was determined by what is known as the ink method (DIN 53 364).

Roughness

Roughness Ra of the film was determined to DIN 4768 with a cut-off of 0.25 mm.

Whiteness and opacity

Whiteness and opacity were determined with the aid of a Zeiss, Oberkochen (DE) "ELREPHO" electric reflectance photometer, standard illuminant C, 2° normal observer. Opacity is determined to DIN 53 146. Whiteness is defined as $W = RY + 3RZ - 3RX$.

W = whiteness, RY, RZ and RX = relevant reflection factors when the Y, Z and X color-measurement filter is used. The white standard used was a barium sulfate pressing (DIN 5033, Part 9). A detailed description is given, for example, in Hansi Loos "Farbmessung" [Color measurement], Verlag Beruf und Schule, Itzehoe (1989).

Light transmittance

Light transmittance is measured using a method based on ASTM D1033-77.

Gloss

Gloss was determined to DIN 67 530. The reflectance was measured as an optical value characteristic of a film surface. Based on the standards ASTM-D 523-78 and ISO 2813, the angle of incidence was set at 60°. A beam of light hits the flat test surface at the set angle of incidence and is reflected and/or scattered by this surface. A proportional electrical variable is displayed representing light beams hitting the photoelectronic detector. The value measured is dimensionless and must be stated together with the angle of incidence.

Glass transition temperature

The glass transition temperature T_g was determined using film specimens with the aid of DSC (differential scanning calorimetry) (DIN 73 765). A DuPont DSC 1090 was used. The heating rate was 20 K/min and the specimen weight was about 12 mg. The glass transition T_g was determined in the first heating procedure. Many of the specimens showed an enthalpy relaxation (a peak) at the beginning of the step-like glass transition. The temperature taken as T_g was that at which the step-like change in heat capacity - without reference to the peak-shaped enthalpy relaxation - achieved half of its height in the first heating procedure. In all cases, there was only a single glass transition observed in the thermogram in the first heating procedure.

Example 1

Chips of polyethylene terephthalate (prepared by the transesterification process using Mn as transesterification catalyst, Mn concentration: 100 ppm) were dried at 150°C to a residual moisture below 100 ppm and fed to the extruder for the base layer B. Alongside this, chips of ®Topas 6015 cycloolefin copolymer (COC) from Ticona (COC composed of 2-norbornene and ethylene, see also W. Hatke: Folien aus COC [COC Films], Kunststoffe 87 (1997) 1, pp. 58-62) with a glass transition temperature T_g of about 160°C were also fed to the extruder for the base layer B. The proportional amount of the cycloolefin copolymer (COC) in the entire film was 10% by weight. 1.0% by weight of the UV stabilizer 2-(4,6-diphenyl-1,3,5-triazin-2-yl)-5-hexyloxyphenol (®Tinuvin 1577 from Ciba-Geigy, Basle, Switzerland) and 4% by weight of phosphorus-containing flame retardant were also added.

Tinuvin 1577 has a melting point of 149°C and is thermally stable up to about 330°C. The UV stabilizer Tinuvin 1577 is fed in the form of a masterbatch. The masterbatch is composed of 5% by weight of Tinuvin 1577 as active component and 95% by weight of PET with a standard viscosity of SV (DCA) = 810, corresponding to an intrinsic viscosity IV (DCA) of 0.658 dl/g.

The flame retardant is the organic phosphorus compound dimethyl methylphosphonate, ®Amgard P 1045 from Albright & Wilson, which is soluble in PET.

The flame retardant is also fed in the form of a masterbatch. The masterbatch is composed of 20% by weight of flame retardant and 80% by weight of PET with a standard viscosity SV (DCA) of 810.

The two masterbatches had bulk densities of 750 kg/m³. Extrusion followed by stepwise longitudinal and transverse orientation was used to produce a white, opaque, single-layer film with an overall thickness of 23 µm.

Base layer B was a mixture of:

85.0% by weight of	polyethylene terephthalate homopolymer with an SV of 800
10.0% by weight of	cycloolefin copolymer (COC) from Ticona, Topas 6015
1.0% by weight of	Tinuvin 1577
4.0% by weight of	Amgard P 1045

The production conditions in the individual steps of the process were:

Extrusion:	Temperatures	Base layer:	280°C
	Take-off roll temperature:		30°C
Longitudinal stretching:	Temperature:		80-125°C
	Longitudinal stretching ratio:		4.2
Transverse stretching:	Temperature:		80-135°C
	Transverse stretching ratio:		4
Setting:	Temperature:		230°C
	Duration:		3 s

The film had the required good properties and the desired handling properties, and the desired processing performance. The properties achieved in films produced in this way are shown in Table 2.

Example 2 (inventive)

A change was made from Example 1 by adding 50% by weight of regrind to the base layer. The amount of COC in the film thus produced was again 10% by weight, the amount of UV stabilizer was 1% by weight, and the amount of flame retardant was

4% by weight. The process parameters were unchanged from Example 1. A visual observation was made of any yellow coloration of the film. It can be seen from Table 2 that hardly any yellow coloration of the film could be observed.

5 Base layer B was a mixture of:

42.5% by weight of polyethylene terephthalate homopolymer with an SV of 800

50.0% by weight of regrind (90% by weight of polyester + 10% by weight of Topas 6015 + 1% by weight of Tinuvin 1577)

5.0% by weight of cycloolefin copolymer (COC) from Ticona, Topas 6015

0.5% by weight of Tinuvin 1577

2.0% by weight of Amgard P 1045

Example 3 (inventive)

Example 1 was now modified by producing a film of thickness 96 μm . The amount of COC in the film was 8% by weight, the amount of Tinuvin 1577 was 1% by weight, and the amount of flame retardant was 4% by weight. The process parameters were unchanged from Example 1. A visual observation was made of any yellow coloration of the film. It can be seen from Table 2 that no yellow coloration of the film was observed.

20 Base layer B was a mixture of:

87.0% by weight of polyethylene terephthalate homopolymer with an SV of 800

8.0% by weight of cycloolefin copolymer (COC) from Ticona, Topas 6015

1.0% by weight of Tinuvin 1577

4.0% by weight of Amgard P 1045

Example 4 (inventive)

A change was made from Example 3 by adding 50% by weight of regrind to the base.

The amount of COC in the film was again 8% by weight, the amount of Tinuvin 1577 was 1% by weight, and the amount of flame retardant was 4% by weight. The process parameters were unchanged from Example 1. A visual observation was made of any yellow coloration of the film. It can be seen from Table 2 that hardly any yellow coloration of the film could be observed.

Base layer B was a mixture of:

43.5% by weight of polyethylene terephthalate homopolymer with an SV of 800

50.0% by weight of self-generated regrind (90% by weight of polyester + 10% by weight of Topas 6015 + 1% by weight of Tinuvin 1577)

4.0% by weight of cycloolefin copolymer (COC) from Ticona, Topas 6015

0.5% by weight of Tinuvin 1577

2.0% by weight of Amgard P 1045

Comparative Example 1

Example 1 from DE-A 2 353 347 was repeated. The example was modified with concomitant use of 50% by weight of regrind. It can be seen from Table 2 that marked yellow coloration of the film was observed. In addition, the roughness of the film is much too high for many applications, and the gloss is too low for many applications. It is highly probable that this is attributable to the use of other polymeric additives.

Base layer B was a mixture of:

47.5% by weight of	polyethylene terephthalate homopolymer with an SV of 800
50.0% by weight of	self-generated regrind (95% by weight of polyester + 5% by weight of polypropylene)
2.5% by weight of	polypropylene

5 Comparative Example 2

Example 1 from EP-A 0 300 060 was repeated. The example was modified with concomitant use of 50% by weight of regrind. It can be seen from Table 2 that marked yellow coloration of the film was observed. In addition, the roughness of the film is much too high for many applications, and the gloss is too low for many applications. It is highly probable that this is attributable to the use of other polymeric additives.

Base layer B was a mixture of:

45.0% by weight of	polyethylene terephthalate homopolymer with an SV of 800
50.0% by weight of	self-generated regrind (95% by weight of polyester + 5% by weight of polypropylene)
5.0% by weight of	polypropylene

Comparative Example 3

Example 1 from EP-A 0 360 201 was repeated. The example was modified with concomitant use of 50% by weight of regrind. It can be seen from Table 2 that marked yellow coloration of the film was observed. In addition, the roughness of the film is much too high for many applications, and the gloss is too low for many applications. It is highly probable that this is attributable to the use of other polymeric additives.

Base layer B was a mixture of:

40.0% by weight of	polyethylene terephthalate homopolymer with an SV of 800
50.0% by weight of	self-generated regrind (95% by weight of polyester + 5% by weight of polypropylene)
10.0% by weight of	polypropylene

5 Comparative Example 4

Example 1 from DE-A 195 40 277 was repeated. The example was modified with concomitant use of 50% by weight of regrind. It can be seen from Table 2 that marked yellow coloration of the film was observed. In addition, the roughness of the film is much too high for many applications, and the gloss is too low for many applications. It is highly probable that this is attributable to the use of other polymeric additives.

Base layer B was a mixture of:

43.5% by weight of	polyethylene terephthalate homopolymer with an SV of 800
50.0% by weight of	self-generated regrind (95% by weight of polyester + 5% by weight of polystyrene)
6.5% by weight of	polystyrene

Each of the films produced in Examples 1 to 4 and Comparative Examples 1 to 4 was exposed to 1000 hours per side of weathering with an Atlas Ci65 Weather-Ometer.

The films produced in the inventive Examples 1 to 4 showed no significant changes in properties.

In contrast, the films of Comparative Examples 1 to 4 showed surface cracks and embrittlement phenomena after 1000 hours of weathering with an Atlas Ci65 Weather-Ometer. It was therefore impossible to measure any accurate property profile for these films, in particular their mechanical properties. In addition, the films

showed marked visible yellow coloration.

Each of the films produced in Examples 1 to 4 and Comparative Examples 1 to 4 was treated at a temperature of 100°C for 200 hours in a circulating-air drying cabinet.

5 The mechanical properties of the films of Examples 1 to 4 are unchanged. The films show not even the slightest sign of embrittlement phenomena, whereas the films of the comparative examples have cracks visible to the naked eye and attempts to fold them lead to fracture.

10 The films of Examples 1 to 4 comply with the requirements for construction material classes B 2 and B 1 to DIN 4102 Part 2/Part 1, and they pass the UL 94 test, but this is not true for the films of Comparative Examples 1 to 4.